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14. ABSTRACT High power microwave tubes are used for both civilian and military applications. Due to the power requirement, tremendous amount of electrons (up to 102A/cm2) are extracted from the cathodes and bombard on the anodes with very high kinetic energy. Overheating, out-gassing, and formation of secondary electrons of the anode cause serious problems. Preliminary results at the AFRL suggest that carbon coating can reduce SE. We investigated the effect of carbon nanotube (CNT) coating on the anode surface. Initial experiments show that CNT is more efficient in absorbing SE compared to the reference metal at low energy. Further experiments at are required to study and understand the effect at high energy.					
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CARBON NANOTUBE BASED ANODE FOR HIGH POWER MICROWAVE TUBES

AFOSR GRANT #F49620-03-1-0396

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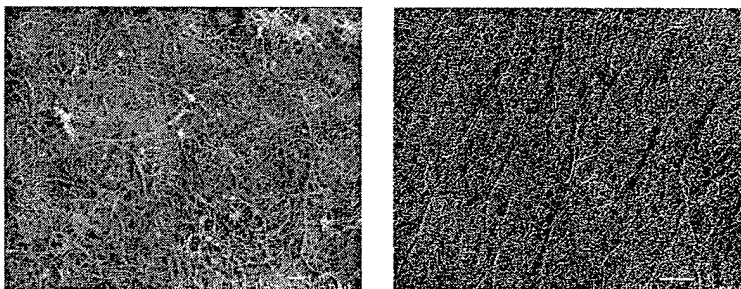
High power microwave tubes are used for both civilian and military applications. Due to the power requirement, tremendous amount of electrons (up to 10^2 A/cm^2) are extracted from the cathodes and bombard on the anodes with very high kinetic energy. Overheating, out-gassing, and formation of secondary electrons of the anode cause serious problems. Preliminary results at the AFRL suggest that carbon coating can reduce SE. We investigated the effect of carbon nanotube (CNT) coating on the anode surface. Initial experiments show that CNT is more efficient in absorbing SE compared to the reference metal at low energy. Further experiments are required to study and understand the effect at high energy.

Research Objective

The objective of this research is to understand the effect of surface structure and morphology on secondary electron emission under high energy electron bombardment. In particular, we aimed at (1) designing processes to deposit CNTs with controlled structure and morphology over a large anode surface; and (2) investigating the formation of secondary electrons from different CNTs coatings under electron bombardment.

Experimental results**1) Sample preparation:**

Uniform CNT film was deposited on the anode surface by an electrophoresis process developed in our lab[1, 2]. In brief, preformed single-wall carbon nanotubes (SWNTs) were first processed and dispersed in isopropyl alcohol (IPA). A small amount of "charger" was added to the solution. The SWNTs were then deposited onto the surface of the anode by DC electrophoretic deposition (EPD). The film thickness was



SEM images of different types of CNT coating fabricated in our labs. Left: low density SWNTs; Middle: high density SWNTs; Right: MWNTs on a curved surface

controlled by the current and deposition time. The morphology and packing density were in part controlled by the aspect ratio of the CNTs used. To increase the adhesion between the CNTs and the substrate, adhesion-promoting metal particles were added to the electrophoretic bath. The sample was then vacuum annealed to remove the residual solvent. The SEM images below show two films made. Sample 1 used long SWNTs while sample 2 used shortened SWNTs.

2) Measurement of secondary electron emission

An in-house field-emission scanning electron microscope (FE-SEM) equipped with both an SE detector and backscattered (BSE) electron detector was used to estimate the SE from the different sample. The system was first calibrated against a standard Au sample using the experimental data available from David C. Joy's Electron-Solid Interaction Database which provides several different sets of experimental data of SE yields for gold, at various accelerating voltages (in kV). For sake of space, the detailed calibration procedure is not included in the abstract.

In the initial experiment, a comparison between a substrate coated with Au film and the same type of substrate coated with Au and CNTs was made. The measurement was performed in the energy range of 0-30KeV. The results are shown in Fig 2. In the low energy range, below 20KeV, the data clearly shows that CNT coating is more efficient in absorbing SE than Au. The

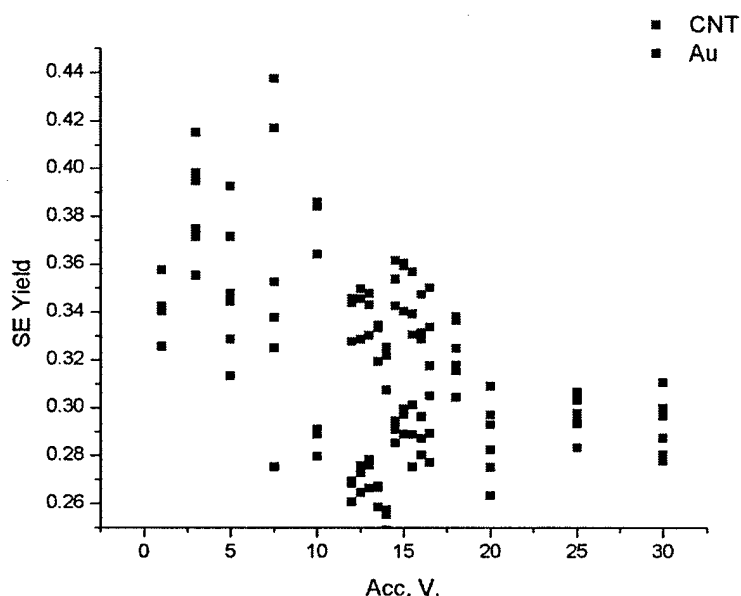


Fig. 2: Secondary electron yield vs. electron energy (Kv)

data above 20KeV is less clear. One of the reasons that can contribute to this is the thickness of the CNTs. In this experiment, the CNT film is on the order of a micron, which may not be sufficient for the high energy electrons.

In summary, we have conducted preliminary experiments on the effect of CNT coating on the SE of anode materials. The initial result shows that at the low electron energy, CNT is shown to be efficient in absorbing the SEs. Further experiments are required to investigate the effect at high energies.

Acknowledgment/Disclaimer

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Publications

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